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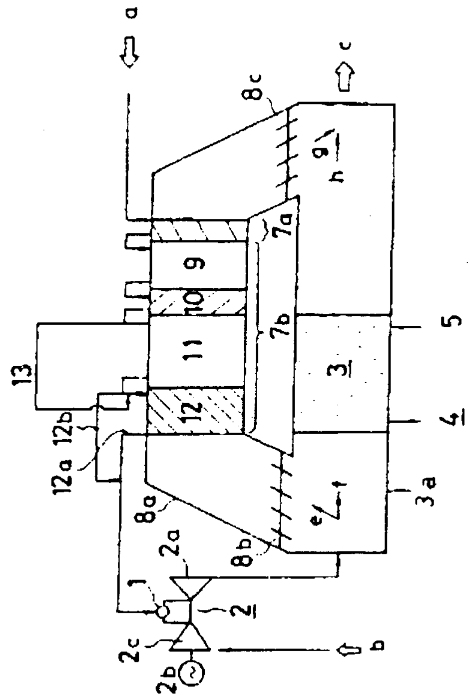

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APPLICATION NUMBER : 61229156

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INT.CL. : F01K 23/02 F01K 23/10

TITLE : COMBINED POWER GENERATING SYSTEM

ABSTRACT : PURPOSE: To intend to reduce an amount of required catalyst by constituting the system in such a way as setting up a reactor with a held-in catalyst which makes fuel vapor evaporated in a evaporator to react chemically for converting said vapor to a secondary fuel with higher fuel energy to superheat said secondary fuel to be supplied to a gas turbine generator system.

CONSTITUTION: Fuel (a) is supplied to a gas turbine generator system 2 through a main fuel line 12a after raised in its temperature through heat exchanging with gas turbine exhaust gas (e) in a fuel treating system. This exhaust gas (e) is adjusted by an inlet damper and an outlet damper 8b, 8c at a branch duct so as to meet the quantity of consumed fuel, and the rest exhaust gas (f) is led to a exhaust boiler system 3 for generating steam and this generated steam is supplied to a steam turbine generator system 4. The fuel treating system is constituted by arranging a superheater 12, a reactor 11, a heater 10, an evaporator 9 and a fuel preheater 7a from flow-in side of the exhaust gas (e). And a catalyst used for endothermic chemical reaction is held only in the reactor 11 for making the fuel vapor from the evaporator 9 to react chemically to be converted to the secondary fuel.

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(54) Title of the Invention: A composite/combined power generating system

(21) Application Number: S61–229156
(22) Filing Date: September 27, 1986

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Specifications

1. Name of the Invention

A combined power generating system

2. Claims

We claim

A combined power generating system characterized by the fact that it possesses:

a gas turbine power-generating system; an exhaust main duct which circulates high-temperature exhaust gas from this gas turbine power-generating system; an exhaust branch duct which is placed so as to form a connection between the upper and lower end sections of this exhaust main duct; a steam turbine power-generating system which is placed between the inlet and outlet of the above-mentioned exhaust branch duct inside the above-mentioned exhaust main duct and which is driven by means of high-pressure steam; and a fuel preheater placed in the above-mentioned exhaust branch duct that preheats fuel supplied in the above-mentioned gas turbine power-generating system by means of the thermal energy of the exhaust gas circulating in the above-mentioned exhaust branch duct;

an evaporator which vaporizes the fuel which has been preheated by the fuel preheater;

a reactor which possesses a catalyst that converts the fuel vapors which have been vaporized by the evaporator into secondary fuel with high fuel energy by means of a chemical reaction;

and a superheater which superheats the secondary fuel from the reactor and supplies it to the above-mentioned gas turbine power-generating system.

3. Detailed Explanation of the Invention

[Field of Industrial Application]

This invention relates to a combined power-generating system with a gas turbine power-generating system and a steam turbine power-generating system, and in particular pertains to a combined power-generating system in which the fuel handling system is improved.

[Prior Art]

Recently combined power-generating systems in which a gas turbine power-generating system and a steam turbine power-generating system driven by the exhaust heat energy have drawn attention as a new technology in which clean fuels such as LNG vaporized gas can be efficiently used. Figure 7 shows the simplified construction of this type of conventional (Kokai S57-215914) [device]. Fuel a is regularly supplied to combustion device 1 by way of fuel preheating device 7a and fuel vaporizer (fuel evaporizer) 7b, which is internally equipped with a reaction catalyst. The above-mentioned fuel a is burned together with air for fuel use b which has been compressed in compressor 2c and gas turbine power-generating system 2 is driven by the energy of the burning fuel. Gas turbine power-generating system 2 is constructed by being equipped with gas turbine 2a and air compressor 2c which is on the receiving end of generator 2b, driven by the turbine output, and the above-mentioned air for fuel use b. The high-temperature exhaust gas from gas turbine power-generating system 2 is discharged via exhaust main duct 3a of waste heat boiler system 3.

Exhaust branch duct 3a is placed so that it connects between the upper flow end section and the lower flow end section inside the exhaust main duct 3a. A steam generator 3e, a water supply preheater 3b, and a fuel preheater 7a are provided inside exhaust main duct 3a facing in the direction from the upper flow side to the lower flow side. Fuel vaporizer 7b is provided inside exhaust branch duct 8a.

Branch duct inlet damper 8b and branch duct outlet damper 8c are respectively provided at the inlet section and outlet section of the above-mentioned exhaust branch duct 8a, creating a construction in which it is possible to control the amount of exhaust gas flow which is flowing in branches inside exhaust branch duct 8a. Moreover, the above-mentioned steam generator 3e and water supply preheater 3b are provided in a location between the above-mentioned inlet damper 8b and outlet damper 8c inside exhaust main duct 3a.

Thereupon, fuel a which is supplied to the above-mentioned gas turbine 2a is heated beforehand by fuel preheater 7a inside exhaust main duct 3a and then chemically reacted through the provision of the thermal energy of high-temperature exhaust gas c from gas turbine 2a by means of fuel vaporizer 7b inside exhaust branch duct 8a so that the fuel is converted to secondary fuel with high combustion energy.

Meanwhile, steam which is produced by the above-mentioned exhaust heat boiler system 3 is supplied to the steam turbine of steam turbine power-generation system 4, driving generator 4b so that turbine output is possible. Then, after the above-mentioned steam turbine 4a is driven, steam is supplied to condenser 5 and, after being cooled and liquidified by cooling water d, is supplied to the above-mentioned water supply preheater 3b via cooling water pump 6. It is then heated by steam generator 3e and made into high-pressure steam.

[Problems This Invention Is to Solve]

In the above-mentioned combined power-generating system, the exhaust of fuel a supplied to gas turbine power-generating system 2 undergoes heat absorption by fuel preheater 7a and fuel vaporizer 7b so that it is possible to boost the amount of retained heat. However, to realize this by these means only, an extraordinarily large amount of expensive catalyst is required, which is problematic from the economic perspective. Large amounts of catalyst are needed because various function sections are included in fuel vaporizer 7b and catalyst is provided to function sections in which it is actually not needed.

Accordingly, this invention has as its purpose offering a combined power-generating system in which the amount of high-cost catalyst is minimized and in which equipment costs are held down.

[Means of Solving the Problems]

This invention, in order to achieve the above-mentioned purpose, possesses

a gas turbine power-generating system; an exhaust main duct which circulates high-temperature exhaust gas from this gas turbine power-generating system; an exhaust branch duct which is placed so as to form a connection between the upper and lower end sections of this exhaust main duct; a steam turbine power-generating system which is placed between the inlet and outlet of the above-mentioned exhaust branch duct in side the above-mentioned exhaust main duct and which is driven by means of high-pressure steam; and a fuel preheater placed in the above-mentioned exhaust branch duct that preheats fuel supplied in the above-mentioned gas turbine power-generating system by means of the thermal energy of the exhaust gas circulating in the above-mentioned exhaust branch duct;

an evaporator which vaporizes the fuel which has been preheated by the fuel preheater;

a reactor which possesses a catalyst that converts the fuel vapors which have been vaporized by the evaporator into secondary fuel with high fuel energy by means of a chemical reaction;

and a superheater which superheats the secondary fuel from the reactor and supplies it to the above-mentioned gas turbine power-generating system.

[Effects]

As was described above, a conventional fuel vaporizer is divided into multiple function sections, but because [in this invention] chemical heat absorption is performed and the catalyst is stored only in the reactor, the amount of catalyst is reduced in comparison to the conventional device so that equipment costs are less expensive.

[Working Examples]

Working examples of this invention will be explained below through reference to the figures, with the explanation centering on the points of difference with the convention example shown in Figure 7.

Both the basic construction of a fuel management system and the plant construction are shown in Figure 1 in order to explain one working example of this invention.

Heat exchange of fuel a is carried out with gas turbine exhaust (exhaust for reactor use) e in the fuel handling system, and after the amount of maintained heat is elevated, fuel a is supplied to gas turbine power-generating system 2 from main fuel line 12a. Gas turbine exhaust e is regulated by means of branch duct inlet damper 3b and branch duct outlet damper 3c to correspond to the amount of consumption of fuel a, and the remaining gas turbine exhaust f produces steam in exhaust boiler system 3. This type of combined power-generating system is comprised of gas turbine power-generating system 2 and steam turbine power-generating system 4.

Meanwhile, in the fuel handling system, superheater 12, reactor 11, heater 10, steam generator 9, and fuel preheater 7a are successively provided in the direction from the flow intake side of gas turbine exhaust e to the flow outlet side. The catalyst used in the endothermic chemical reaction is stored only in reactor 11. The above-mentioned superheater 12 and reactor 11 are provided with reactor bypass lines 13 respectively between superheater 12 and combustor 1 of gas turbine power-generating system 2, and between superheater pipeline 12b or reactor 11 and superheater 12.This is used in operation adjustments. There is sometimes performance reduction in the reaction catalyst stored in reactor 11 accompanying a long period of use and in this event, reaction temperature can be increased by using main fuel line 12a.

Either a methanol decomposition reactor or a methanol steam-reforming reactor or both can be used as the above-mentioned reactor 11. In the present case, a methanol decomposition reactor was used with the following equations (1) and (2).

$$CH_3OH \rightarrow CO + 2H_2 \quad \Delta H25°C = 21.7\ \text{kcal/mol} \qquad (1)$$

$$CH_3OH + nH_2O \rightarrow (2+n)H_2 + (1-n)CO + nCO_2 \qquad (2)$$

Here, $0<n<1$

In addition, the following equation (3) is used with a methanol steam-reforming reactor:

$$CH_3OH + H_2O \rightarrow CO_2 + 3H_2 \quad \Delta H25°C = 11.8\ \text{kcal/mol} \quad (3)$$

The following materials were used as the catalyst stored in the above-mentioned reactor 11.

Namely, using a computer simulation based on the combined power-generating system shown in Figure 1 in which exhaust heat of 505°C is introduced into boiler 3, a test was carried out for a filling of platinum catalyst 19 m^3 and nickel-copper system catalyst 19 m^3 used in the case of the above-mentioned reactor 11 being a methanol decomposition reactor, and for a filling of copper-zinc system catalyst 19 mm^3 being used in the case of the above-mentioned reactor 11 being a methanol steam-reforming reactor. Here, a mixed gas of methanol (410 kmol/h) and

steam (410 kmol/h) was supplied at 265°C, a steam-improving reaction carried out in reactor 11, and a 1440 kmol/h gas (gas composition H_2 61.3%, CO 3.1%, CO_2 1[illegible].3%, CH_3OH 7.1%, and H_2O 10.2%) obtained. Methanol of 1360 kmol/h was supplied to this gas from preheater 7a at 265°C, and when a decomposition reaction was carried out in reactor 11, a 4700 kmol/h gas (H_2 61.7%, CO 19.05, CO_2 8.0%, CH_3OH 9.7%, and H_2O 1.2%) obtained. The methanol conversion rate was 90%. Moreover, gas turbine 2a is turned when this gas is burned in combustor 1. Part of the exhaust heat is recovered by exhaust heat boiler 3 and when a steam turbine is turned by the steam produced by the steam generator (not shown), the output of gas turbine 2a was 121600 kW and the output of steam turbine system 4 was 37400 kW, with a power efficiency rate of 47.2% being obtained.

On the other hand, when a test was done based on a computer simulation of a combined power-generating system using a filling of a platinum catalyst and a nickel-copper system catalyst as the fuel vaporizer 7b in Figure 7, methanol (17770 kmol/h) and steam (170 kmol/h) were introduced. Twenty-seven m^3 of palladium catalyst and 54 m^3 of a nickel-copper system catalyst were required to obtain a methanol conversion rate of 90%. Moreover, when the same type of calculations as above were performed, the output of gas turbine system 2 was 121920 kW, and the output of steam turbine system 4 was 35200 kW, with a power generation efficiency rate of 46.6% being obtained.

Figure 2 and Figure 3 illustrate the endothermic conditions for the fuel handling system from gas turbine exhaust e. The amount of converted heart of preheater 7a, evaporator 9, heater 10, reactor 11, and superheater 12 are given as Q subscript. Superheater 12 elevates the [illegible, possibly absorption] heat of fuel a after reaction and performs the Q_{12} heat absorption. However, when main fuel line 12a is completely open, superheater 12 is entirely bypassed, resulting in the endothermic conditions shown in Figure 3. In order to increase the temperature of the inlet gas of reactor 11 from T_2 to T_1, temperature increase q_{11} is applied in reactor 11 and the amount of heat absorbed inside the reactor is increased to Q_{11}'. Therefore, it is possible to ensure a reaction temperature that is higher than that in Figure 2. Reactor bypass line 13 is used when the reaction temperature at times such as starting and stopping equipment operation is lower than specified and maintains the life of the reaction catalyst by reducing heat cycle fatigue. When stopping [equipment operation], measures are taken such as opening reactor pipeline 13 and, at the same time, sealing an inert gas in reactor 11. When reactor bypass line 13 is in use, gas turbine 2 is operated by the vaporized fuel.

The basic construction of a fuel vaporization system is shown in Figure 4, with reactor 11 and superheater 10 of Figure 1 omitted. In this way the ancillary equipment is reduced is comparison to Figure 1 so that cost is further reduced and the placement of each machine is simplified.

Figure 5 shows an applied example of a fuel handling system. (1) is an example corresponding to Figure 1, and (4) is an example corresponding to Figure 4. Moreover, (2) is an example in which fuel preheater 7a is separated from $7a^1$ and placed as $7a^2$ in the confluence duct and (3) is an example in which the water supply preheater of boiler section 3 is separated and placed in on the reactor side.

The fact that the exhaust gas duct is used with two branches is the basis of this invention and the arrangement in Figure 6 will be considered. Namely,

(1), when the duct has a combined flow:

Because the construction is such that there is one exhaust duct, doubling back of the duct is advantageous. Exhaust gas control to reactor 11 is carried out by flow control damper (R) 8b. Gas flow adjustment of the combined flow section is performed with flow control dampers (R) 8c and 8d which link with this.

(2) and (3), when the exhaust ducts are separately connected to the chimney:

Isolation dampers 8c and 8d are both placed on the outlet side of reactor 11 and the boiler outlet side. In this event, isolation dampers 8c and 8d are used for draft stopping during equipment stoppage and, in terms of equipment, can be more simplified than is the case with (1). However, it is necessary to double amount of doubling back of the exhaust ducts.

The following effects can be obtained by means of the implementation examples described above.

(1) Because the construction is such that the catalyst is stored only in reactor 11, in which the chemical heat absorption is performed as in Figure 1, the endothermic plan is simpler than in conventional devices and the amount of catalyst is reduced, making equipment costs lower.

(2) Because the construction of reactor 11 (fuel vaporizer 7b in Figure 7) is made up of superheater 12 / reactor 11 / heater 10 / evaporator 8 / preheater 7a as shown in Figure 1, or superheater 12 / evaporator 9 / preheater 7a as shown in Figure 4, the chemical heat absorption or other physical absorption is carried out in the above-mentioned reactor 11 and it is possible to increase the amount of retained heat of fuel a. As a result, it is possible to obtain a higher efficiency for the combined power-generating system than when using fuel a untreated.

Either a decomposition reaction or a steam-improving reaction of methanol is used in the reactor performing the above-mentioned chemical heat absorption and these reactions can be implemented by respectively specifying the catalyst and its reaction temperature as in the above-mentioned working examples. On the other hand, when there is a large amount of latent heat of vaporization, even if the amount of reatained heat is increased only by this latent heat and the physical absorption of the sensible heat, the combined power-generating efficiency will increase more than in the case of simply using liquid fuel. The degree of increase is lower than in the case of using reaction heat absorption, but the amount of equipment fees is less.

(3) Because super heater bypass line 12b is placed between super heater 12 and fuel device 1 of gas turbine power-generating system 2, it is possible to control performance drop in the reaction catalyst by increasing the temperature of reactor 11. In other words, because super heater bypass line 12 is used to reduce the amount of absorbed heat when the performance of the reaction catalyst drops as is shown in Figure 2 and Figure 3, it is effective in "increasing the temperature of the gas surrounding the reactor in order to maintain reaction efficiency."

(4) Reactor bypass line 13 which is placed between reactor 11 and super heater 12 can be effectively used in cases such as the following: when reactor 11 can not be used as a result

of [illegible] of the reaction catalyst, damage to reactor 11, etc., or in cases in which the reaction temperature has fallen below a specified value due to low plant (that is, gas turbine) load, and to prevent "reduction in catalyst life and performance due to large changes in fuel vapor temperature when reactor 11 is injecting toward 'paiparesu' [term transliterated] catalyst in the event of sudden excessive motion (issued stop)."

[Effects of the Invention]

By means of this invention, as has been described above, it is possible to offer a combined power-generating system in which the amount of catalyst is less than is the case with conventional devices so that equipment costs are reduced because the catalyst is stored only in the reactor which carries out the chemical heat absorption.

4. Brief Explanation of the Figure

Figure 1 is a block construction diagram of one working example of the combined power-generating system of this invention. Figure 2 and Figure 3 are explanatory figures of the results of the operation of Figure 1. Figure 4 is a block construction diagram showing a changed example of Figure 1. Figure 5 shows an application example of the fuel handling system of this invention. Figure 6 shows an application example of the exhaust duct separation of this invention. Figure 7 is a block construction diagram showing one example of a conventional combined power-generating system.

1 ... fuel device, 2 ... gas turbine power-generating system, 2a ... gas turbine, 2b ... generator, 2c ... air compressor, 3 ... exhaust heat boiler system, 3a ... exhaust heat main duct, 4 ... steam turbine power-generating system, 4a ... steam turbine, 4b ... generator, 5 ... steam condenser, 7a ... fuel preheater, 8a ... exhaust branch duct, 8b and 8c ... branch duct inlet, outlet dampers, 9 ... evaporator, 10 ... heater, 11 ... reactor, 12 ... superheater.

Sub-agent Takeo Suzue, Patent Attorney

Figure 1

Figure 2

[middle left] fuel temperature

[upper right] gas turbine [illegible] temperature

[lower right] amount of converted heat (kcal / [illegible] kg)

Figure 3

[lower right] amount of converted heat (kcal [illegible])

Figure 4

Figure 5

Figure 6

[within figure] or none

or none

Figure 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/00626

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02C7/224 F01K23/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02C F01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X	EP 0 634 562 A (SCHARPF) 18 January 1995 see page 4, line 30 - line 38; figures ---	1-4,21
X	DE 20 05 656 A (METALLGESELLSCHAFT) 19 August 1971 see page 10, last paragraph - page 12, line 21; figure ---	1-4,18, 21,23
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 315 (M-735), 26 August 1988 & JP 63 085207 A (MITSUBISHI HEAVY IND LTD), 15 April 1988, see abstract ---	1-4,10, 11, 18-21,23

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
20 April 1998	24/04/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Gheel, J

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/00626

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